FIG. 2 is a perspective view of the external programming unit of FIG. 1.

FIG. 3 is a block diagram of the implanted device from FIG. 1.

FIG. 4 is a cross sectional view of an implanted pacemaker in which the present invention may be practiced.

FIG. 5 is an ECG tracing depicting atrial synchronous (VDD) pacing (on Lead II) obtained from the external programming unit of FIG. 2, and a timing diagram thereof.

FIG. 6 is a block diagram of the sensing circuit practiced within the present invention.

FIG. 7 is a detailed block diagram of the SEA P-wave morphology detector circuit.

Fig 8 is a TABLE 1 of a summary of the open loop performance of the P-wave detectors described in FIGs. 6 and 7.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of an implantable medical device system adapted for use in accordance with the present invention. The medical device system includes an implantable, modified VVI pacemaker 10 implanted in a patient 12. One ventricular pacemaker lead 14 is electrically coupled to pacemaker 10 in a conventional manner and extends into the patient's heart 16 via a vein 18. Near the distal end of lead 14 are one or more exposed conductive electrodes for receiving electrical cardiac signals and/or for delivering electrical pacing stimuli to heart 16.

Also depicted in FIG. 1 is an external programming unit 20 for non-invasive communication with implanted device 10 via uplink and downlink communication channels. Associated with programming unit 20 is a programming head 22 for facilitating two-way communication between implanted device 10 and programmer 20.

could be due to several causes, e.g., sinus bradycardia, sinus pause, sinus block, etc. Post-ventricular atrial refractory period 7 generally serves two purposes. Its associated blanking period is meant to prevent sensing of ventricular pacing pulse 2, commonly called "far-field R-wave sensing." Such sensing, if allowed to occur, could be interpreted by the pacemaker as another P-wave to which it would synchronize a ventricular output pulse, leading to a form of pacemaker mediated tachycardia (PMT). The period of time after the blanking period is called by various terms, among them, "noise sampling period." Atrial events, sensed within this period will not start AV interval timing 5. Ventricular refractory period 9 also has an associated blanking period (shaded area). The purpose of this blanking period is to prevent self-inhibition, that is, sensing of ventricular pacing pulse 2 and paced r-wave 3. The remaining portion of ventricular refractory period 9 is also a noise sampling period. Any R-wave sensed in this period resets, or restarts, the ventricular refractory period.

This brief description of the underlying timing of VDD pacing will serve as a touchstone for further art. Each of these vital timing sequences, as well as others to be mentioned as appropriate to the art, must be accounted for to ensure VDD pacing in the absence of an atrial lead within the heart.

FIG. 6 is a block diagram of the electronic sensing circuitry used in pulse generator (~~FIG 1~~, 10) in accordance with the presently disclosed invention. There are three signal inputs to the analog-digital converter (ADC) unit 35. The ventricular electrogram (VEGM) is a primary input and is transmitted via the ventricular lead (~~FIG 1~~, 14) located in the apex of the right ventricle. This signal input consists of the intrinsic ventricular depolarization waveform which, when received and processed, inhibits the scheduled ventricular output pulse. Subcutaneous electrode array (SEA) 13 is also a primary input and provides ECG data to the ADC on a continuous basis.

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of the signal or one of various morphology metrics that may be programmed by the clinician. Assuming, however, that the signals are deemed valid, they are sent out to stimulation control unit (Fig. 21). P-wave detects 46 initiate an AV interval, whereas the R-wave detects 47 serve to inhibit the scheduled ventricular output pulse.

FIG. 7 is a detailed block diagram of SEA P-wave morphology detector circuit 45, comprised of two sub blocks. SEA P-wave event buffer 45a has both a circular and linear data buffer. SEA data is continuously stored in the circular buffer until a P-wave threshold crossing occurs 44. At that time, the circular buffer is frozen and the linear buffer starts to fill. The linear buffer freezes after a set number of samples are stored. When frozen, event buffer 45a contains a potential P-wave. The potential P-wave in event buffer 45a is then analyzed by P-wave morphology detector 45b to determine if a valid P-wave is present.

P-wave morphology detector 45b decision function is based either on the width of the signal in event buffer 45a of one of various morphology metrics. The width is defined as the duration of the minimum window about the P-wave threshold crossing 44 point where the signal at the left endpoint of the window is at or below the baseline value. The baseline is assumed to be zero (0), but can be determined adaptively. If the user selects a morphology metric, the potential P-wave in event buffer 45a is compared to a P-wave template using the selected metric. These metrics are: correlation, absolute difference, or mean square difference and are defined as follows.